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MEMORANDUM REPORT NO. 1939

AERODYNAMIC FORCE TESTS OF CONE CYLINDER FLECHETTE MODELS AT SUPERSONIC MACH NUMBERS (U)

by

Klaus O. Opalka

October 1968

19990317088

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BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1939

OCTOBER 1968

AERODYNAMIC FORCE TESTS OF CONE CYLINDER FLECHETTE MODELS AT SUPERSONIC MACH NUMBERS (U)

Klaus O. Opalka

Exterior Ballistics Laboratory

[illegible]

RDT&E Project No. 1T22901A201

ABERDEEN PROVING GROUND, MARYLAND

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BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1939

KOOpalka/lca
Aberdeen Proving Ground, Md.
October 1968

AERODYNAMIC FORCE TESTS OF CONE CYLINDER FLECHETTE MODELS AT SUPERSONIC MACH NUMBERS (U)

(UNCLASSIFIED) ABSTRACT

Wind tunnel force tests were performed to determine the influence of varying afterbody length on the aerodynamic characteristics of five slender cone cylinder flechette models. The test was performed in the supersonic wind tunnel No. 1 of the U.S. Army Ballistic Research Laboratories. Force and static stability parameters were determined at Mach numbers 1.5 to 4.0 at nearly constant Reynolds numbers. The results are presented and compared with theoretical data obtained from supersonic small disturbance theory.

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(UNCLASSIFIED) TABLE OF CONTENTS

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(UNCLASSIFIED) LIST OF ILLUSTRATIONS

(UNCLASSIFIED) LIST OF ILLUSTRATIONS

(UNCLASSIFIED) LIST OF SYMBOLS

C_A	zero lift total axial force coefficient, $F_A/\left(\frac{\pi}{4} d^2 q_\infty\right)$
C_{PB}	base pressure coefficients, $\left(p_\infty - p_B\right)/q_\infty$
C_{AFo}	zero lift forebody axial force coefficient, $C_{Ao} - C_{PB}$
C_M	pitching moment coefficient (reference at the model base), $M/\left(\frac{\pi}{4} d^3 q_\infty\right)$
C_N	normal force coefficient, $F_N/\left(\frac{\pi}{4} d^2 q_\infty\right)$
$C_{N\alpha o}$	slope of normal force curve, $\partial C_N/\partial\alpha$, for zero angle of attack
d	reference model diameter
F_A	axial force
F_N	normal force
M_∞	free stream Mach number
M	pitching moment (reference at the model base)
p_∞	free stream pressure
p_B	base pressure
q_∞	free stream dynamic pressure $(\gamma/2)\ p_\infty\ M_\infty^2$
Re_d	Reynolds number based on reference model diameter and free stream conditions
X_{CP}	center of pressure location with reference to the cone cylinder junction or to the model base (in calibers)
X_{CYL}	length of the cylindrical afterbody (in calibers)
α	angle of attack
γ	ratio of specific heats

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(CONFIDENTIAL) 1. INTRODUCTION

Nonspinning very slender bodies of revolution were stabilized in the past primarily by an array of tail mounted fins. These fins, however, have caused many problems since they have been in use. They are usually of a weak structure and, therefore, prone to be damaged. Seen from this point of view, mass stabilization appears to be advantageous over fin stabilization. Interest has arisen recently in the technique of mass stabilizing these bodies, referred to as flechettes.

Therefore, an investigation was initiated by the U.S. Army Munitions Command, Picatinny Arsenal. O'Keefe and Wassermann[1] found from a literature review that the most promising flechette configurations consisted of 8 to 10 caliber cones with a short afterbody of 1.5 to 3.0 calibers in length. They further determined the optimum cone for their purposes to be 8.85 calibers. Having their choice narrowed down by these findings, the investigators contacted the Ballistic Research Laboratories (BRL) at the Aberdeen Proving Ground and asked that the Exterior Ballistics Laboratory perform a wind tunnel force test on five flechette models at Mach numbers between 1.5 and 4.0 in order to determine the influence of the varying length of the afterbody on the aerodynamic characteristics of the flechettes.

The test was performed in July 1966, and the results are published in this report. Furthermore, they are also compared with theoretical data[2], obtained from supersonic small disturbance theory.

Apart from this program, a free flight investigation was conducted in the range of the Exterior Ballistics Laboratory[3]. Thirteen rounds of the shortest model version (Configuration 1), measuring 0.2 inch in diameter at the base, were fired in February 1967 in order to obtain aerodynamic data. Seven of these rounds yielded good results and were included in this report for comparison.

Earlier experimental work on cone cylinders was published in 1954 by L. E. Schmidt[4], who investigated the dynamic properties of pure cones and cone cylinders, and by W. E. Buford and S. Chatunoff[5], who studied the effects of fineness ratio and Mach number on the normal force and the center of pressure of cone cylinders. The current data provide additional information on the flow past cone cylinders for configurations not investigated previously.

(UNCLASSIFIED) 2. EXPERIMENTAL INVESTIGATION

The tests were conducted in the Supersonic Wind Tunnel No. 1 of the Exterior Ballistics Laboratory, BRL.

2.1 Equipment

The supersonic wind tunnel No. 1[6] is continuously operated and has a closed circuit. The test section is 15 inches high and 13 inches wide, and the angle of attack ranges from -10 to +15 degrees. Figure 1 shows a picture of the test section with the model (Configuration 1) installed. The flexible nozzle is calibrated for 15 Mach numbers between 1.5 and 5.0; accuracy of the calibration is ± 0.01 absolute error. The Reynolds number can be varied between 0.1×10^6 and 0.6×10^6 per inch.

A three component strain gage balance was used in the test to detect the aerodynamic forces acting on the model. Its load capacities are

Normal force	12 lbs. between gages
Axial force	5 lbs.

The external dimensions of the balance, belonging to a set of eight are given in Figure 2.

For determining the contribution of the base pressure on the axial force, the base pressure was measured through a 1/16 inch diameter flexible tube and monitored by a pressure transducer of appropriate range.

The model dimensions are given in Figure 3. All five configurations consist of the same cone, measuring 8.85 calibers in length and 1.15 inches in diameter at the base. The cylindrical afterbody varies in length from 1.5 to 3.5 calibers.

2.2 Procedure

The test schedule and the test conditions are given in the following table

M	$Re_d \times 10^{-6}$	Configurations
1.5	.541	1 2 3 4 5
	.276	1 3 5
2.0	.552	1 2 3 4 5
	.265	1 3 5
2.5	0.541	1 2 3 4 5
	0.265	1 3 5
3.0	.541	1 2 3 4 5
	.173	1 3 5
3.5	0.564	1 2 3 4 5
	0.276	1 3 5
4.0	0.564	1 2 3 4 5
	0.276	1 3 5

After the flow was established, the standard procedure was to record the aerodynamic forces every full degree angle of attack beginning with the maximum angle (11°) and proceeding towards its minimum value (-6°). A zero angle of attack reference check is made at the beginning and at the end of each test run. To obtain more test points for the determination of the derivatives of normal force and pitching moment, readings were taken every half degree between plus and minus two degrees. Schlieren photographs were taken at zero degree angle of attack.

2.3 Data Reduction

The data were reduced on the BRL computer (ORDVAC) using the standard program for three component measurements. The derivative of the normal force at zero lift, $C_{N\alpha o}$, was averaged analytically and graphically from seven test points between +2 and -2 degrees. The analytical method employed to obtain the derivative was that of least squares. The results of both methods were compared in order to eliminate erroneous test points affecting the least squares fit.

From calibration data and repeatability tests, the accuracy of the data was estimated to be better than 0.05 and 0.1 absolute error in the normal and axial force coefficients respectively and 0.1 calibers in the center of pressure. The derivative of the normal force coefficient was found to be accurate within 3% of its value.

All angles of attack have been corrected for strut deflection due to aerodynamic load and for the flow inclination in the tunnel.

(UNCLASSIFIED) 3. THEORETICAL PREDICTION

Extensive theoretical studies of the supersonic flow past cone cylinders have been made at the BRL by Clippinger, Giese and Carter[7] in 1950 using the method of characteristics. During the past few years, R. L. McCoy[2] has been providing predictions on cone cylinder models based on supersonic small disturbance theory. This latter method avoids the disadvantages of the method of characteristics (laborious and time consuming) and yet provides adequate accuracy for most practical cases.

The current computational scheme is based on Van Dyke's hybrid theory[8]. It consists of a second order solution for the axisymmetric flow past slender bodies of revolution onto which a first order approximation of the cross flow is superimposed. This inviscid flow model yields a pressure distribution that is integrated and resolved into normal and axial force components. The method has proven excellent agreement with the method of characteristics.

Corrections accounting for the effects of viscosity were also incorporated into the program. The principal contributions of viscosity at the considered Mach numbers (1.5 thru 5.0) arise from skin friction, boundary layer thickness and flow structure in the near wake. The latter will influence the base pressure.

Van Driest's theory for laminar and turbulent compressible boundary layers[9] was selected for the calculation of skin friction. Chapman's and Sternberg's[11] theories were chosen to obtain a prediction of the base pressure.

(UNCLASSIFIED) 4. RESULTS

The experimental results of the wind tunnel test are presented in two groups of graphs. In the first group, the basic aerodynamic coefficients are plotted versus angle of attack. In the second group, the influence of afterbody length and Mach number on the force and static stability coefficients at zero angle of attack is shown, and the experimental results are compared with the theoretical prediction.

4.1 Basic Aerodynamic Coefficients Versus Angle of Attack

The normal force coefficient, C_N, the center of pressure, X_{CP}, the total axial force at zero lift, C_{A_0}, and the base pressure coefficient, C_{PB}, are plotted versus angle of attack in Figures 4 through [illegible]. The data of one configuration at all Mach numbers and at constant Reynolds number are assembled on a single sheet. For completeness sake all test data are presented including those at the lower test Reynolds number (0.27×10^6). These data are intended to serve as background for the summary data and for further information. In the following evaluation, however, only the test data at the higher test Reynold's number (0.55×10^6) have been considered.

4.2 Aerodynamic Coefficients Versus Afterbody Length and Mach Number

The influence of the afterbody and the Mach number on the center of pressure are shown in Figures 12 and 13. The two groups of curves represent two reference positions on the model. The data of the upper group represent the center of pressure as measured from the base of the model. In the lower group the location of the C.P. is given with respect to the cone cylinder junction, i.e. the base of the cone alone. In Figure 14 the C.P. location of the shortest (1) and the longest (5) flechette configuration are compared with the results of the theoretical prediction prepared by R. L. McCoy[2]. Some of the free flight test data of Configuration 1 are also included for comparison.

The effect of afterbody and Mach number on the slope of normal force curve is shown in Figures 15 and 16. Figure 17 presents a comparison of the experimental data with the prediction for Configurations 1 and 5.

The data for the base pressure and the axial force are given in Figures 18 through 20. The base pressure coefficient (Figure 19) and the total axial force coefficient (Figure 20) are compared with the results of the prediction. Drag data obtained from free flight tests are included in Figure 20.

(CONFIDENTIAL) 5. DISCUSSION

The primary objective of the wind tunnel test was to determine the center of pressure (C.P.) position on the model. In addition, the other data were obtained representing the remaining properties of the model with regard to lift and drag.

5.1 Center of Pressure

The distance between the center of mass (C.G.) and the center of pressure (C.P.) on the model

$$D = X_{CG} - X_{CP}$$

is the most important parameter for the originator of this wind tunnel test[1]. Highest possible stability is obtained when the distance between the two centers is greatest; that is to say that the C.G. should lie as forward as possible on the model and the C.P. as aft as possible.

The method of stabilization being investigated is to add a light cylindrical skirt to a massive cone in an attempt to move the C.P. aft with only a slight adverse effect on the C.G. If the mass of the skirt is enough to influence the C.G. significantly, then the advantage is partly or even completely offset.

The results in Figure 12 (lower curves) show that the C.P. moves aft with increasing cylinder length only by a small amount (0 - 0.5 caliber C.P. caliber cylinder length) depending on the Mach number, and it can be concluded that the method is not very effective particularly at the lower test Mach numbers (M = 1.[illegible] - [illegible]).

The influence of the Mach number on the C.P. location may be seen in Figure 13. Here the model with the shortest afterbody appears to be advantageous as the C.P. location will change least among the model series during the flight from higher to lower Mach numbers.

A comparison between our experimental data, McCoy's theoretical prediction[illegible] and the available free flight test results[2] is given in Figure 14. The experimental data fall between the curve for inviscid flow and that one corrected for fully turbulent boundary layer. (The correction for laminar boundary layer was not available.) In fact, the boundary layer of the wind tunnel models was found to be predominantly laminar, the transition occurring somewhere on the rear portion (second half) of the model (see also section 5.3). The free flight and wind tunnel data agree quite well and the differences between prediction and experiment amount to 13% of the theoretical values. The Reynolds number based on model diameter range from 1.4 x [illegible] at Mach number 1.5 to 4.1 x 10[illegible] at Mach number 3.5 for the free flight data. The wind tunnel data were measured at nearly constant Reynolds number ($5.5 \times 10^5 \pm .1 \times 10^5$).

5.2 Slope of the Normal Force Curve

The influence of the afterbody length on the slope of the normal force curve, $C_{N\alpha}$, (Figure 15) increases with increasing Mach number. The change in the slope of the fittings in Figure 15 from zero to positive values combined with the reversal in the magnitude of the value of $C_{N\alpha}$ for the shorter afterbody lengths has also been observed by Buford and Shatunoff in their investigation of the effects of the afterbody length of cone cylinder models.

The influence of the Mach number on $C_{N\alpha_0}$ is demonstrated in Figure 16 and the data for the shortest and the longest configuration are compared with the prediction in Figure 17. The deviation between the inviscid flow prediction and the experimental data is generally less than 15% of the theoretical value except for the data of Configuration 1 at and above $M_\infty = 3$.

5.3 Base Pressure

The influence of afterbody length and Mach number on the base pressure are shown in Figure 18. As there is no influence of the afterbody length evident from the tests, only the data of the shortest (1) and the longest (5) flechette configuration are plotted versus the Mach number and the trend is represented by one fitting. A comparison between the experimental findings and the theoretical base pressure prediction is given in Figure 19. The prediction is based on empirical theories[10, 11] which presuppose the existence of a turbulent boundary layer.

A study of the available schlieren pictures disclosed that the boundary layer was predominantly laminar on the wind tunnel tested models and the percentage of turbulent boundary layer along the models appeared to increase with higher Mach numbers. Therefore, the discrepancy between prediction and experiment is not surprising.

5.4 Axial Force

The afterbody length has only a very slight influence on the zero lift axial force stemming from the friction along the afterbody surface, and the data were, therefore, not shown plotted versus this parameter.

A comparison of the results for the axial force versus Mach number obtained from free flight tests, theoretical prediction and the wind tunnel test is shown in Figure 20.

The free flight drag data (obtained at angle of attack varying between 1.5 and 4.0 degrees) appear to agree with the prediction for turbulent boundary layer (at zero angle of attack).

The comparison of the wind tunnel data with the prediction suggests a laminar boundary layer in the wind tunnel test and the difference between theory and experiment could then be explained primarily as the difference between the measured and the predicted base pressure (Figure 19). The coincidence of the predicted and the measured zero lift forebody axial force in Figure 19 confirms that this explanation is correct.

However, the forebody axial force data also indicate (in agreement with flow photographs) that the boundary layer was not fully laminar in the test and that it tended to become more turbulent with increasing Mach number. This may account for a secondary contribution to the differences of the axial force data in Figure 20.

(UNCLASSIFIED) 6. CONCLUSION

The method of mass stabilizing cone cylinder flechettes by increasing the length of a cylindrical skirt up to 3.5 caliber is found to be of little effectiveness. Within the scope of the test, the most favorable C.P. location is obtained for a short cylindrical skirt of 1.5 to 2.5 caliber in length.

The experimental wind tunnel data for the center of pressure agree with the theoretical prediction within 15% and with the available results from free flight tests in the range of this Laboratory within 8%.

The differences in the axial force measurements resulting from the wind tunnel test and from the free flight range test are caused by different boundary layer conditions.

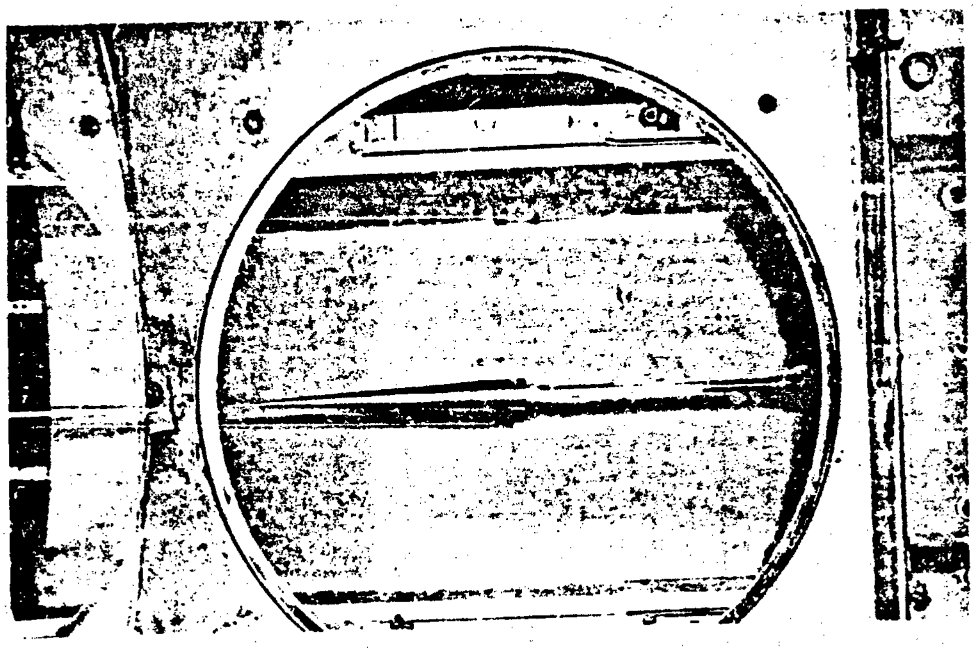


Figure 1. Test Section With Installed Model

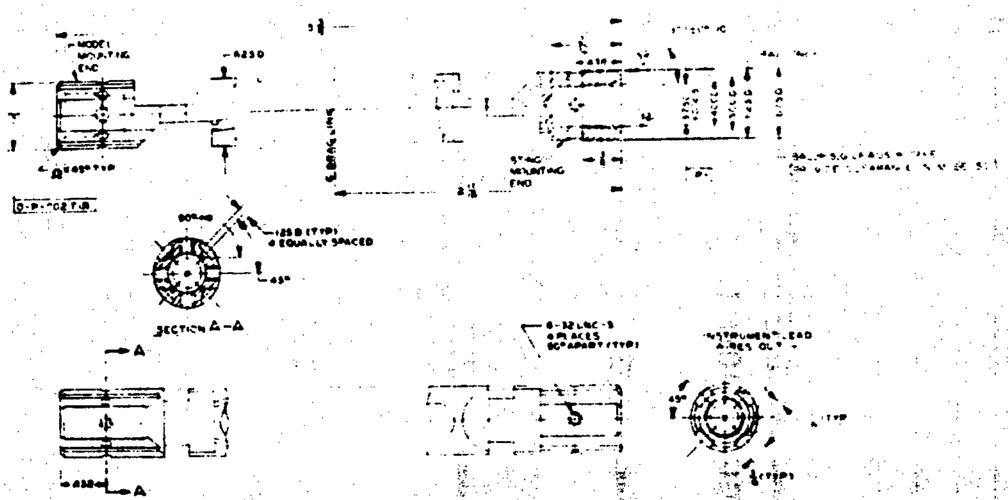
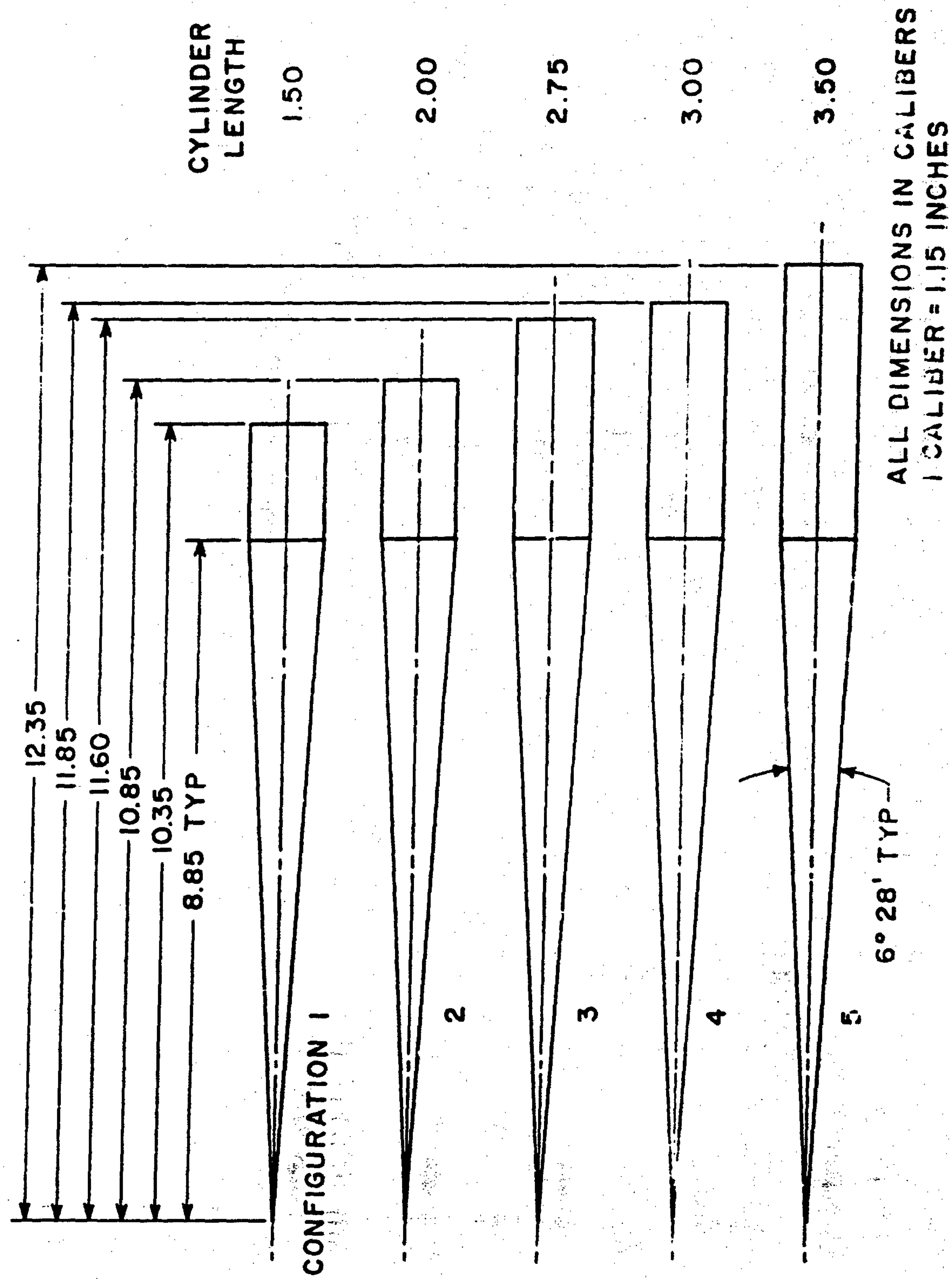


Figure 2. External Dimensions of Balance


CYLINDER LENGTH
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2.00
2.75
3.00
3.50
12.35
11.85
11.60
10.85
10.35
8.85 TYP
6° 28' TYP
CONFIGURATION 1
2
3
4
5
ALL DIMENSIONS IN CALIBERS
1 CALIBER = 1.15 INCHES

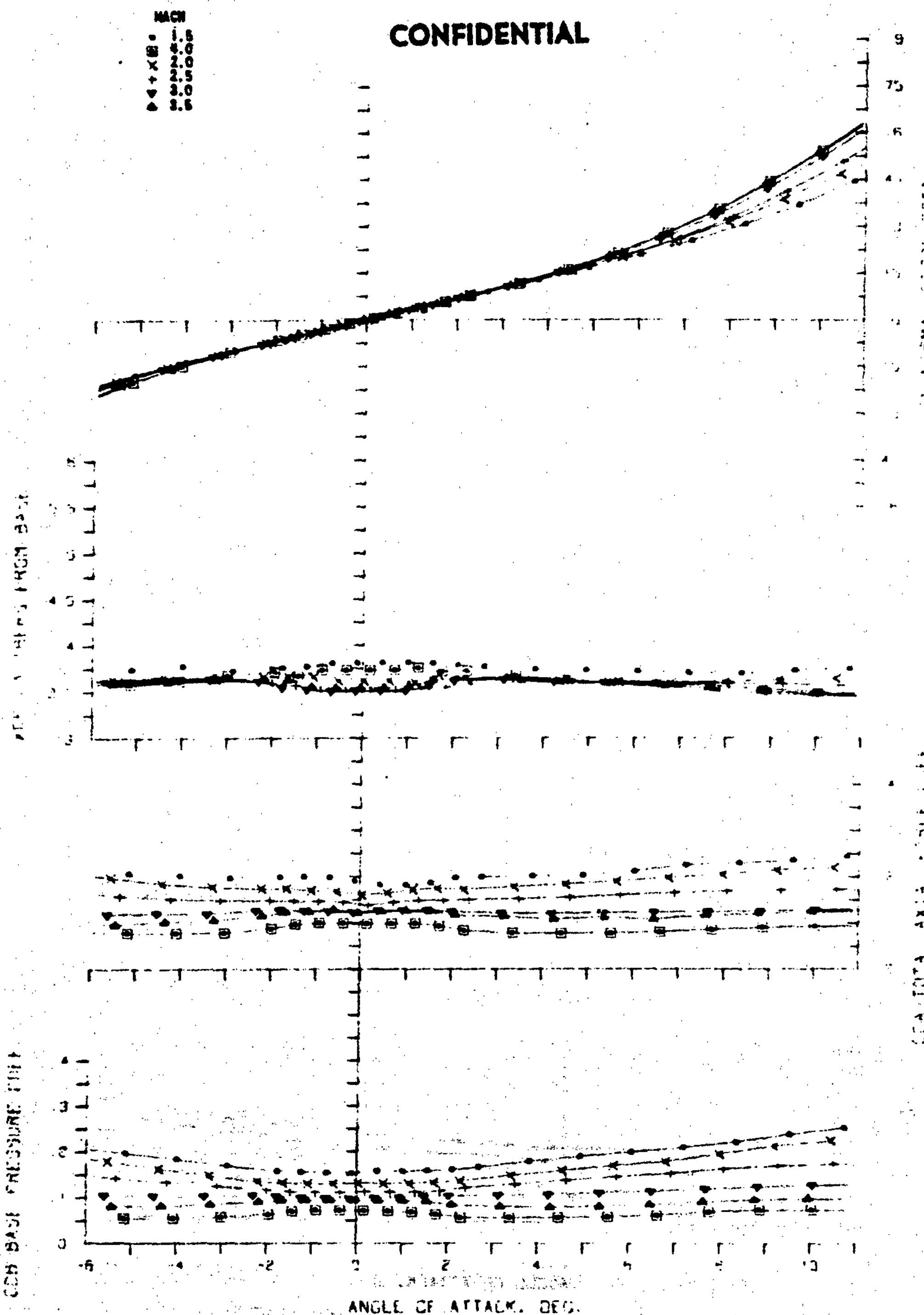


Figure 4. (C) Aerodynamic Coefficients Versus Angle of Attack for Configuration I at $Re_d = 5.5 \times 10^6$ (U)

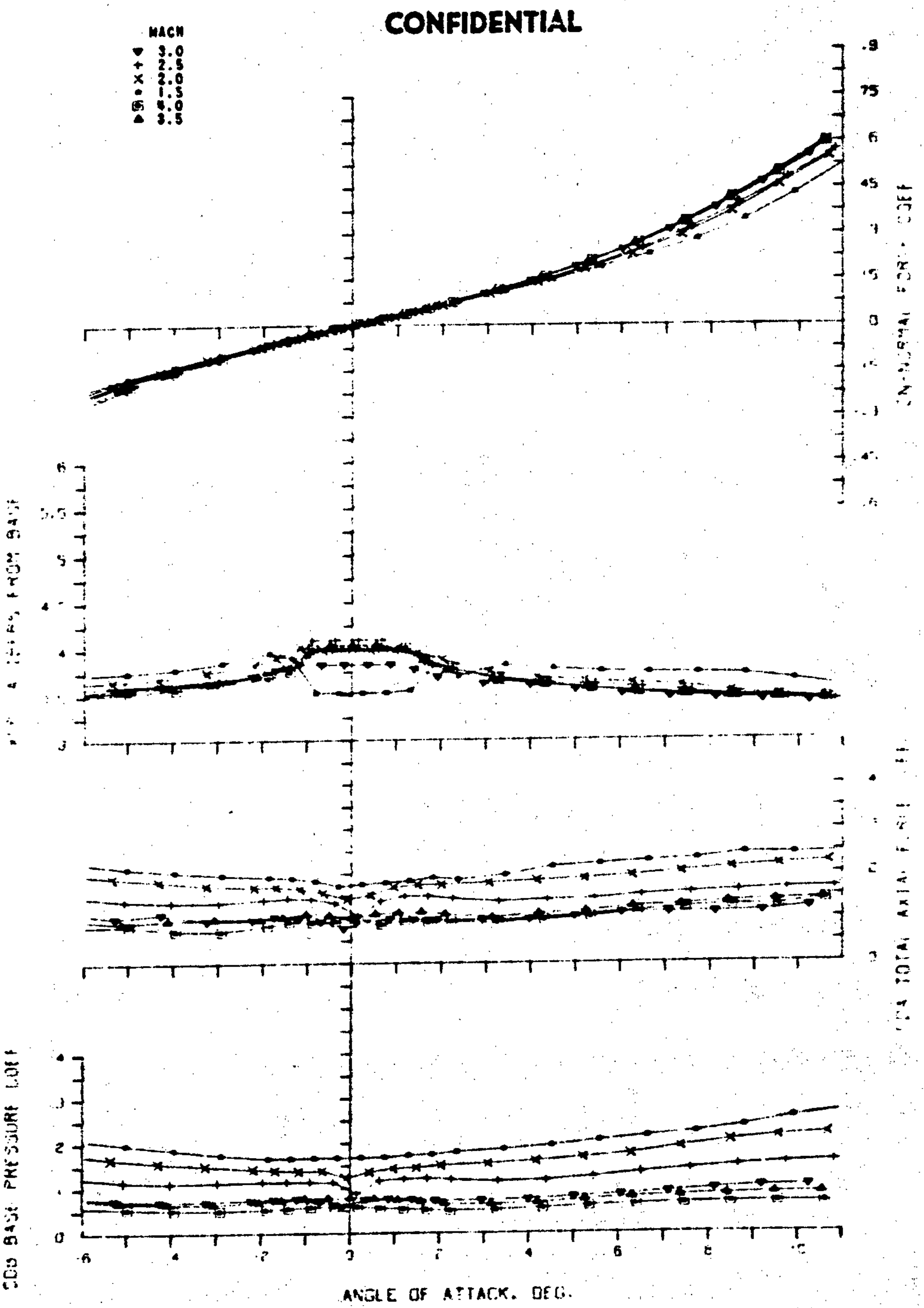
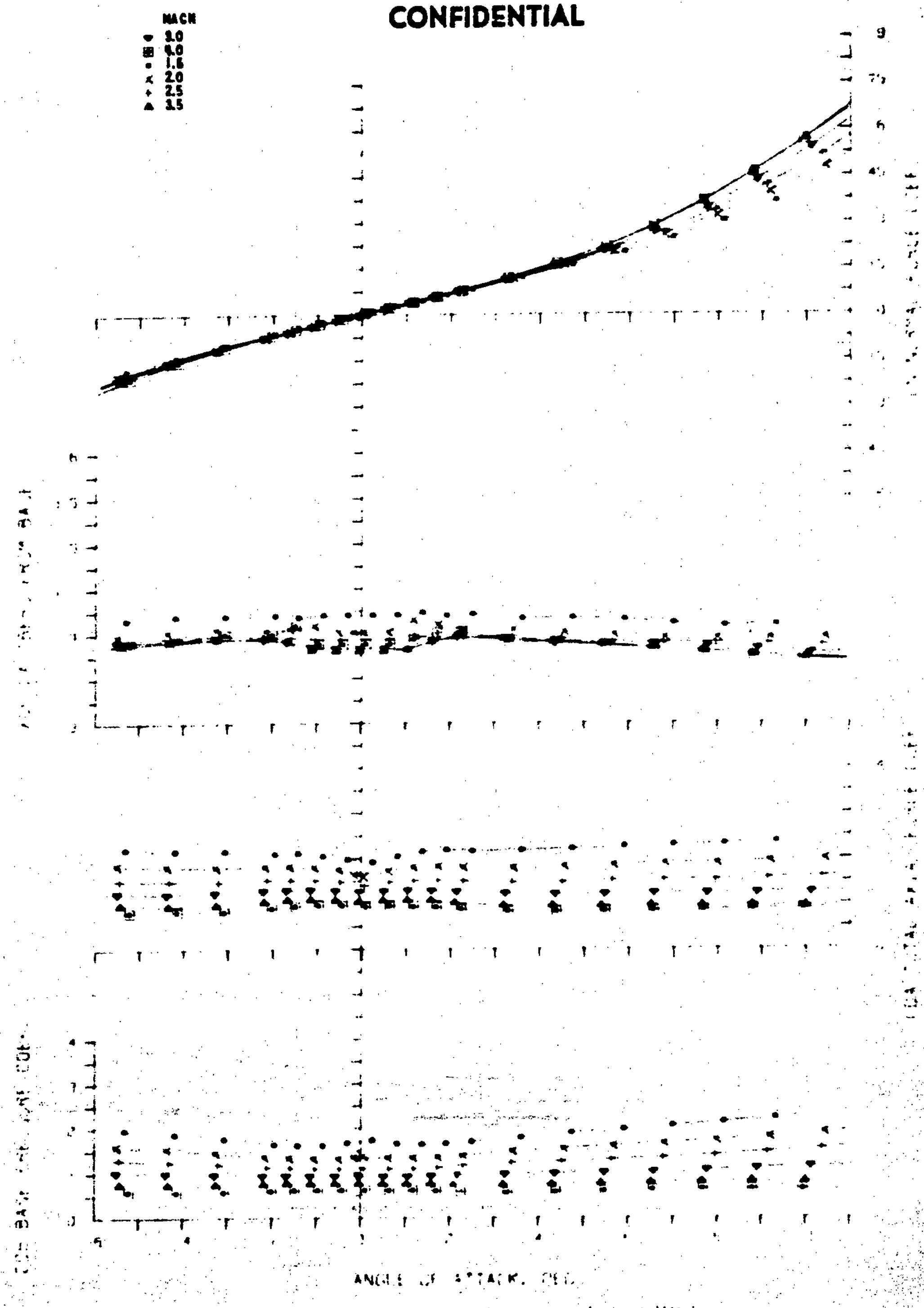


Figure [illegible]. (C) Aerodynamic Coefficients Versus Angle of Attack for Configuration [illegible] at Re_d = [illegible] x 10^5 (U)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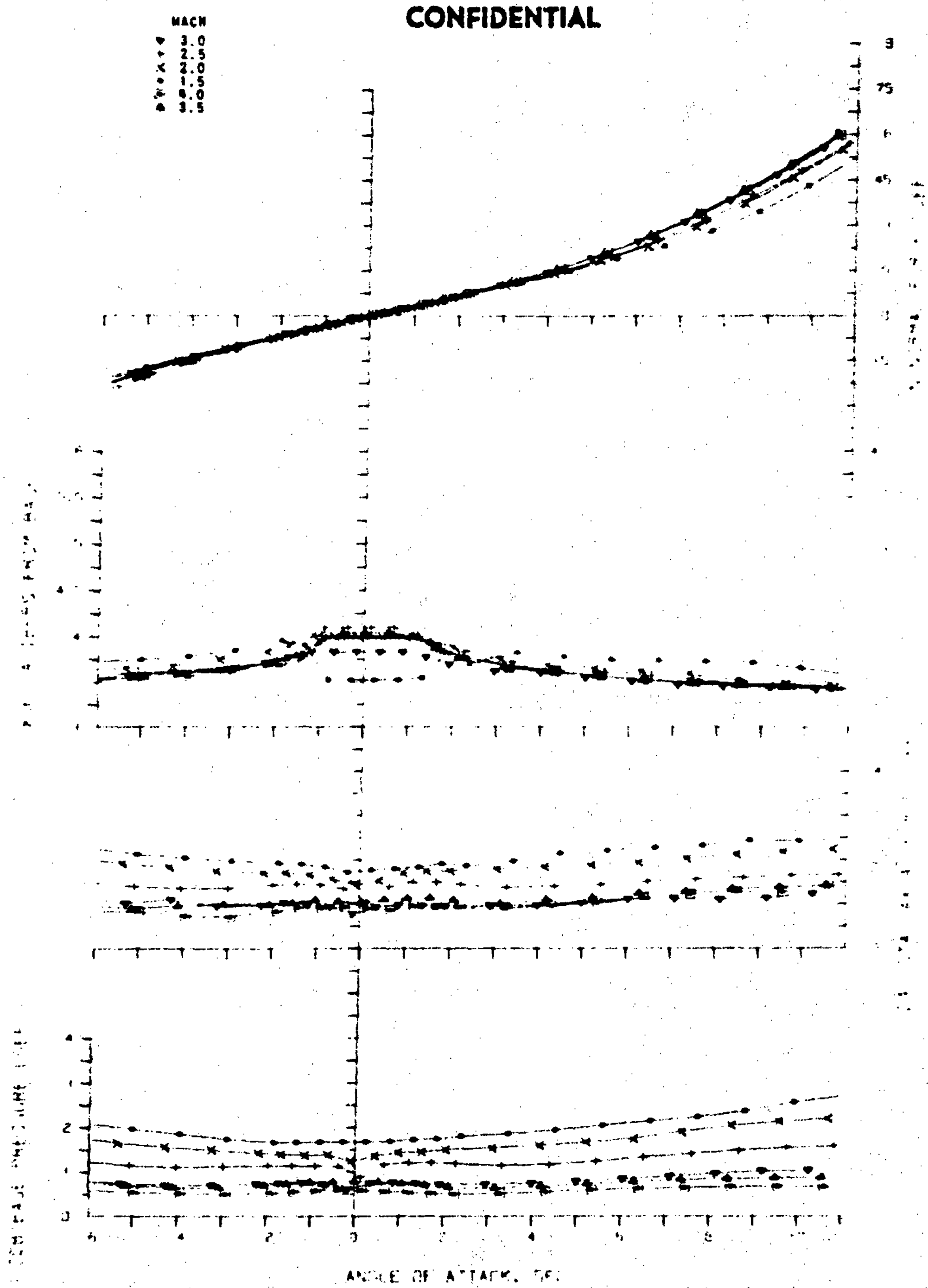
1.6
2.0
2.5
3.5
ANGLE OF ATTACK, DEG.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ANGLE OF ATTACK, DEG

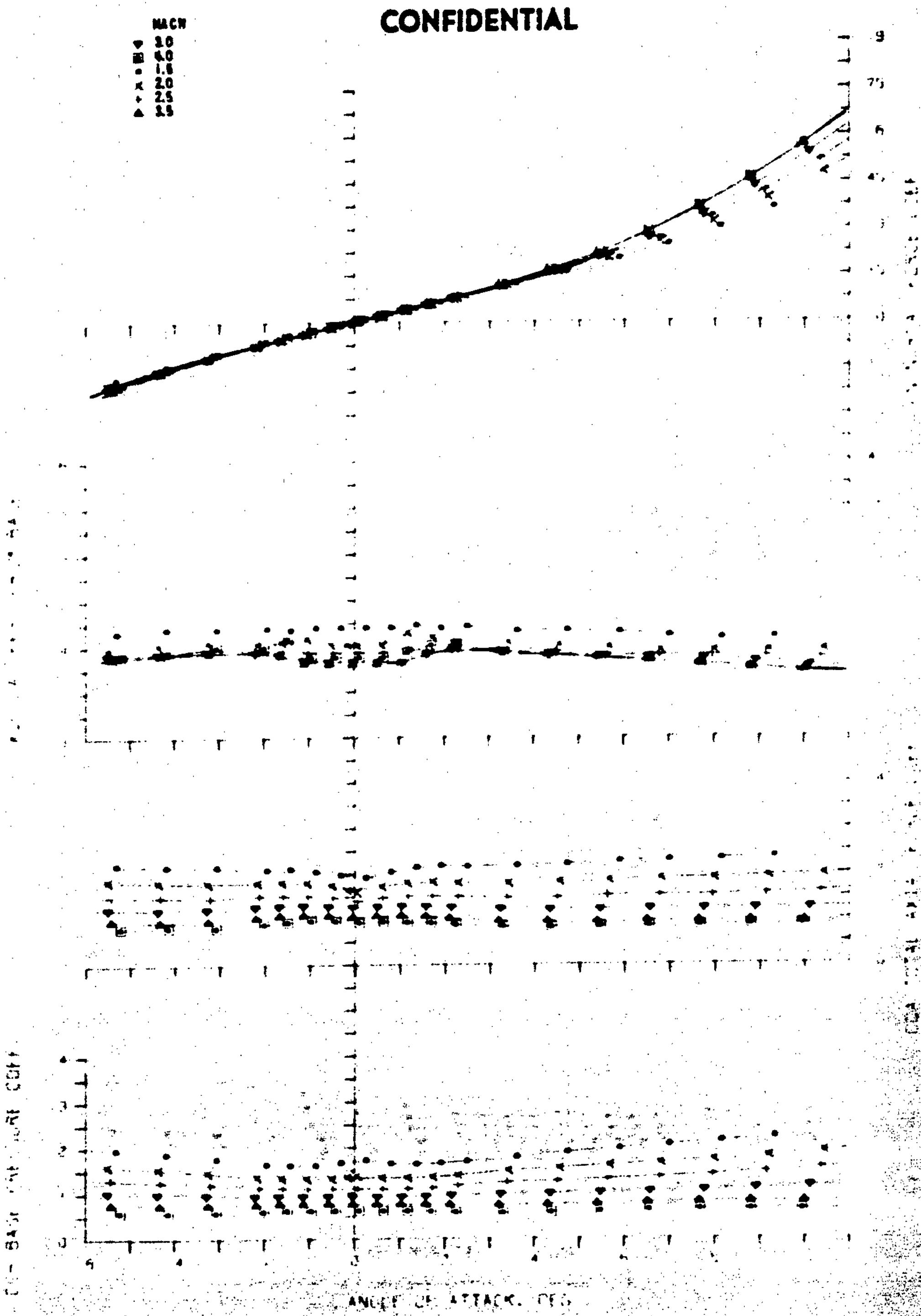

Figure ... (...) Aerodynamic Coefficients Versus Angle of Attack

... Configuration ...

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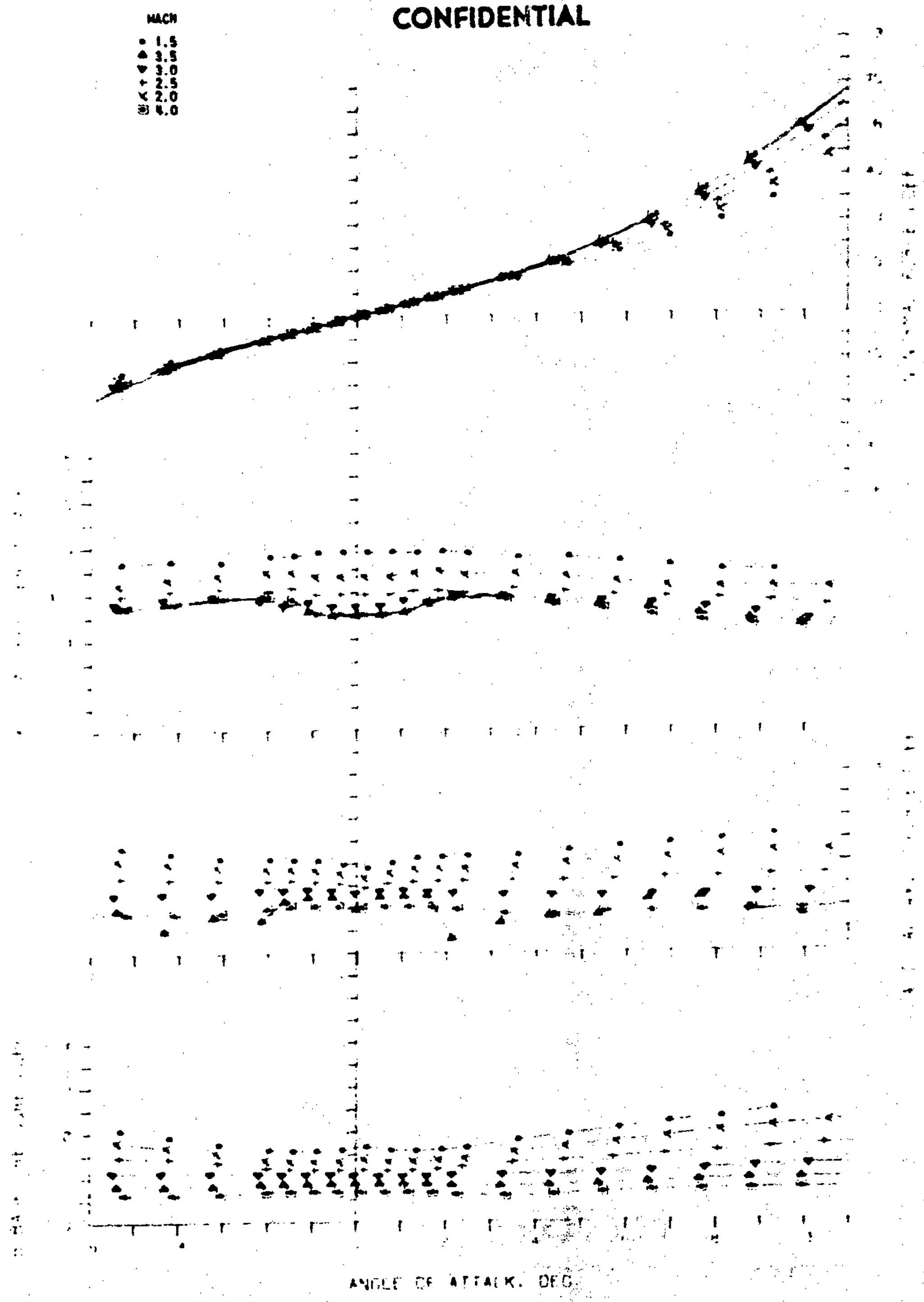

[illegible] (U) Aerodynamic Coefficients versus Angle of Attack [illegible]

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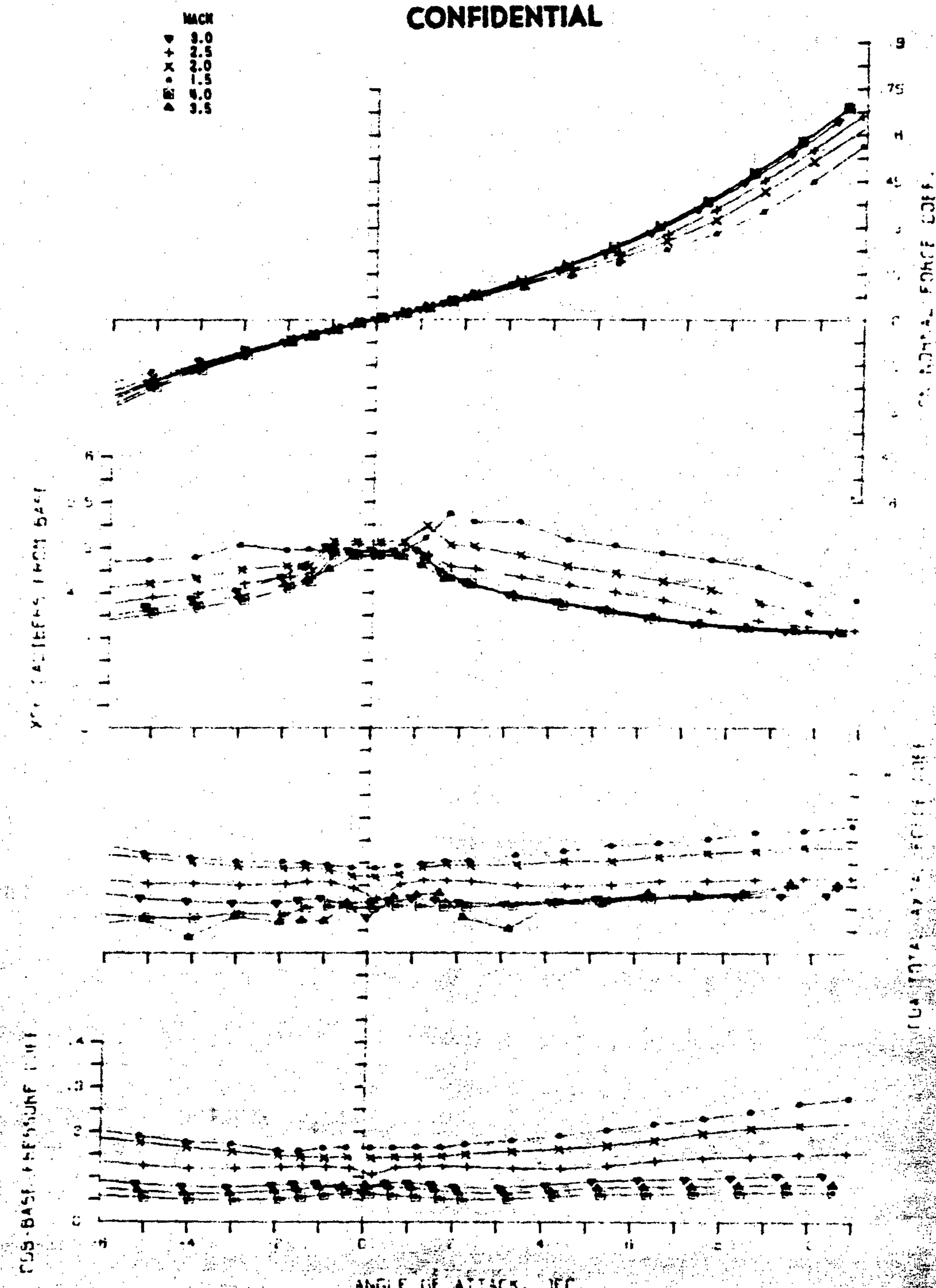

Figure [illegible]. ([illegible]) Aerodynamic Coefficients Versus Angle of Attack for Configuration 3 at [illegible] (U)

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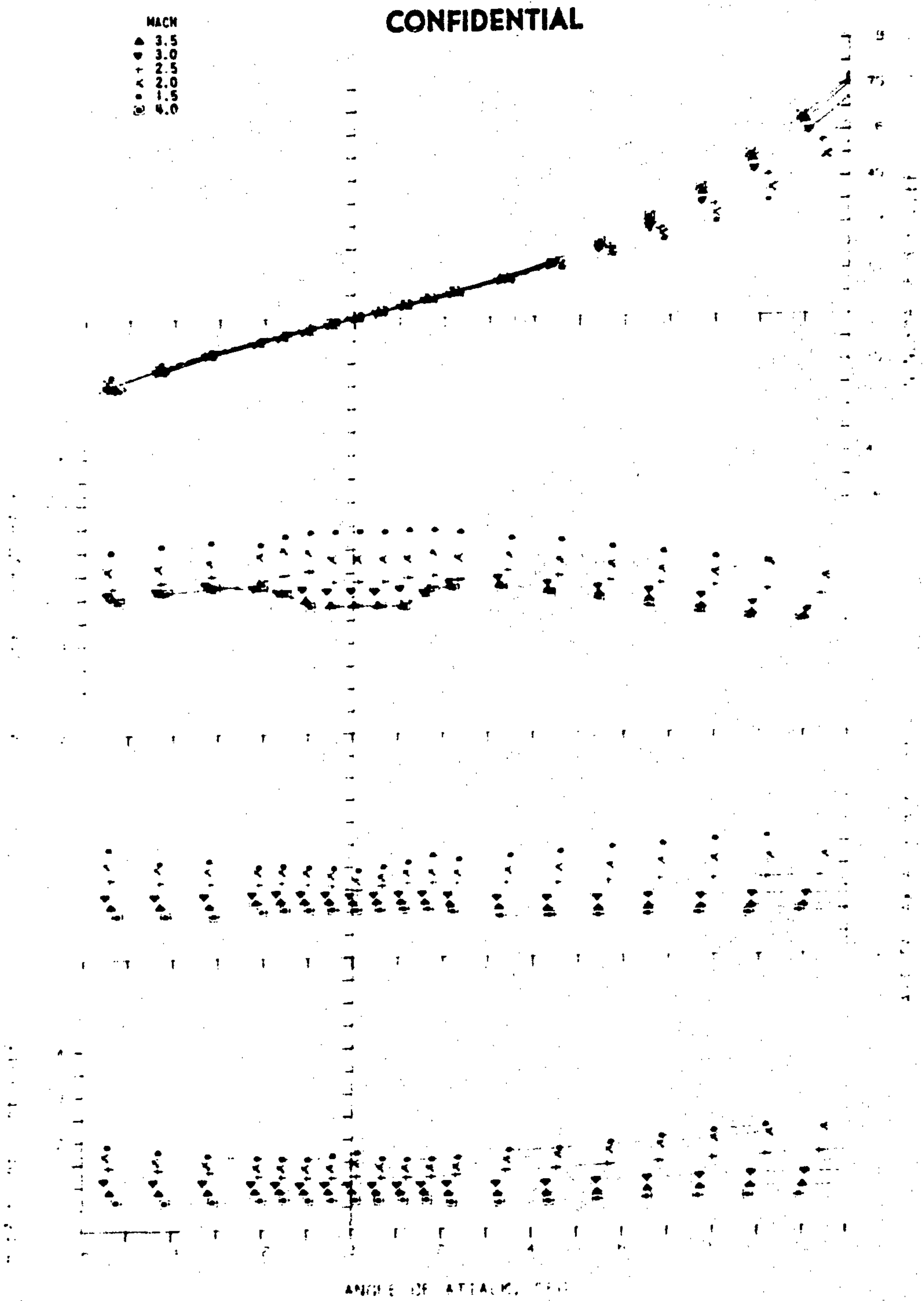

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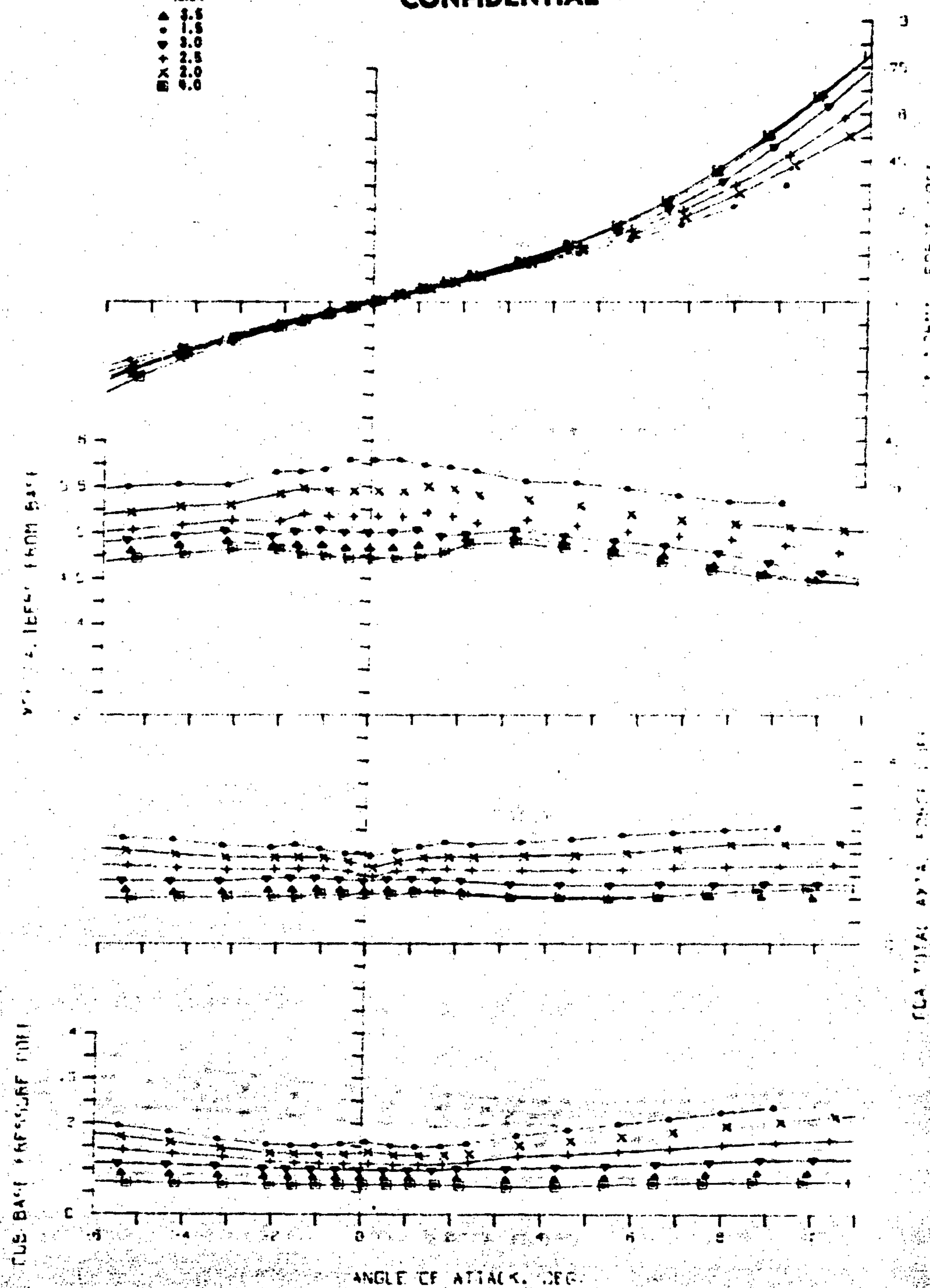


Figure 1[illegible]. (C) Aerodynamic Coefficients Versus Angle of Attack for Configuration [illegible] at Re_d = [illegible] x 1[illegible] (U)

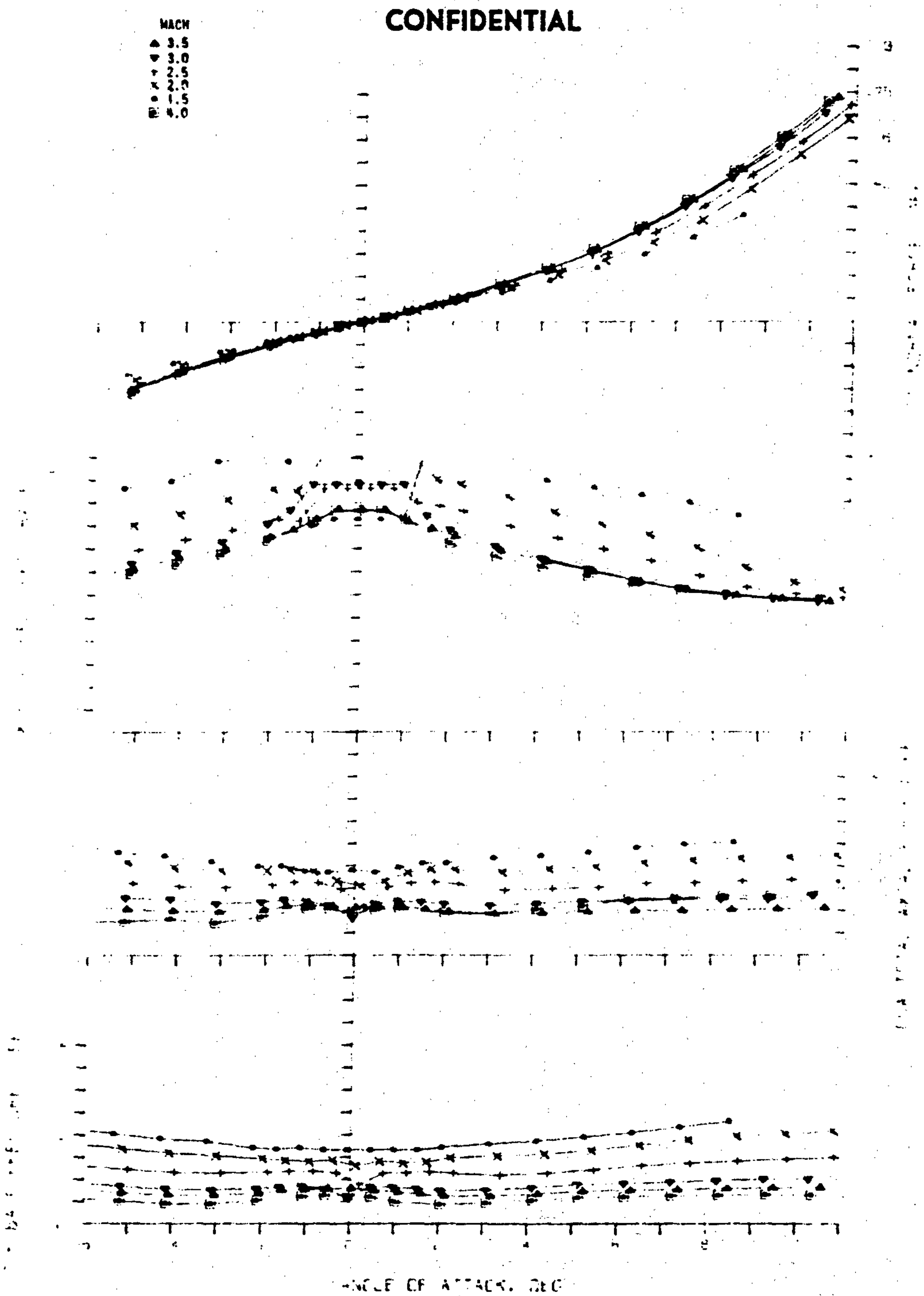


Figure 11. (C) Aerodynamic Coefficients Versus Angle of Attack for [illegible] at Re_d = 2.[illegible] x [illegible] (U)

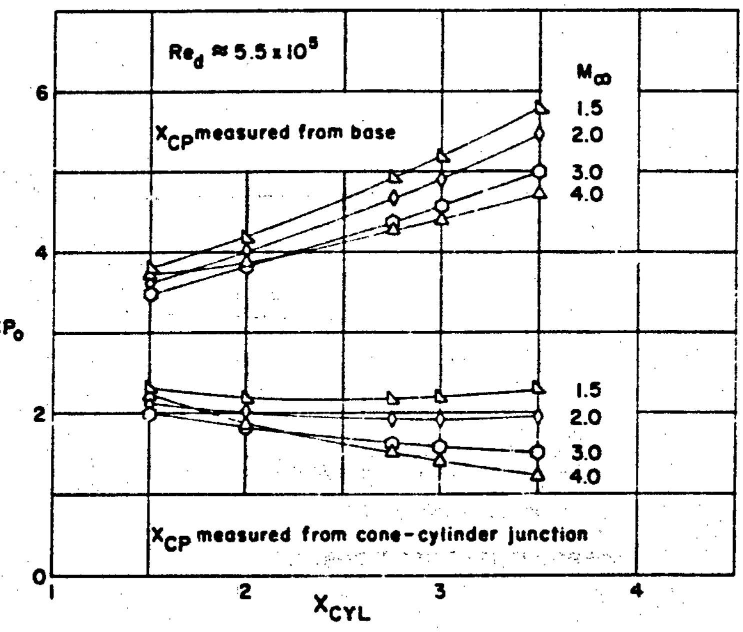
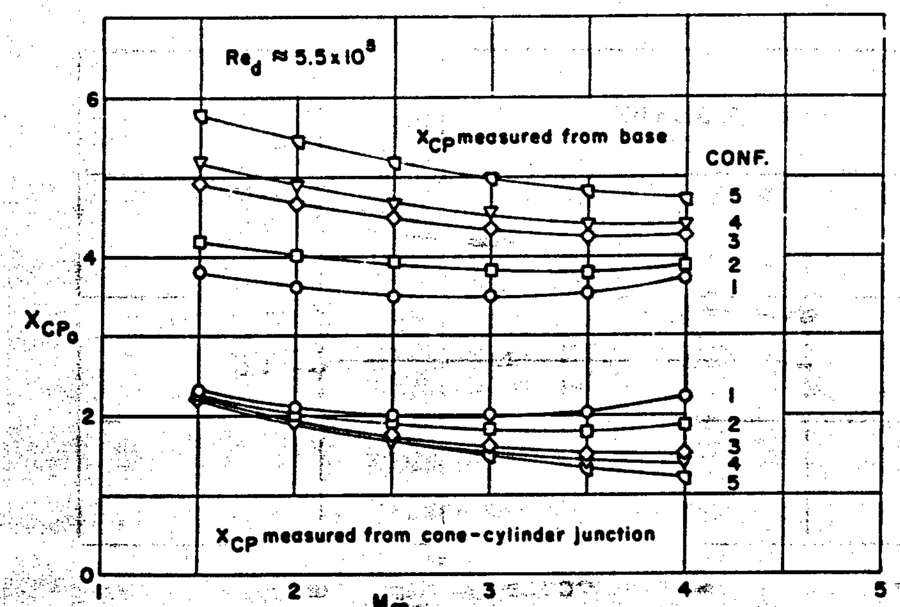


Figure 12. (C) Center of Pressure Location Versus Afterbody Length (U)



(U) Figure 13. (C) Center of Pressure Location Versus Mach Number (U)

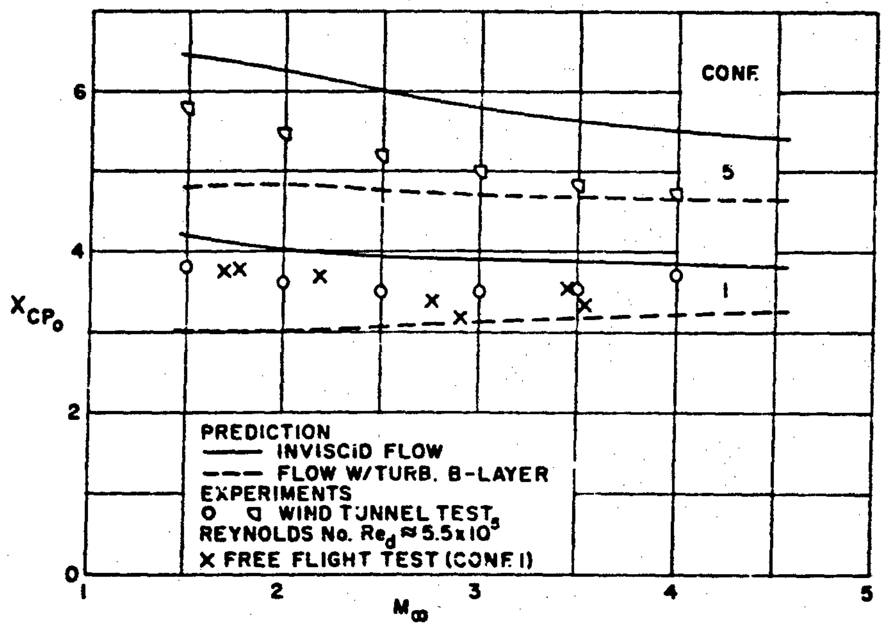


Figure 14. (C)Center of Pressure Location Versus Mach Number - Comparison With Theory and Free Flight Test Data (U)

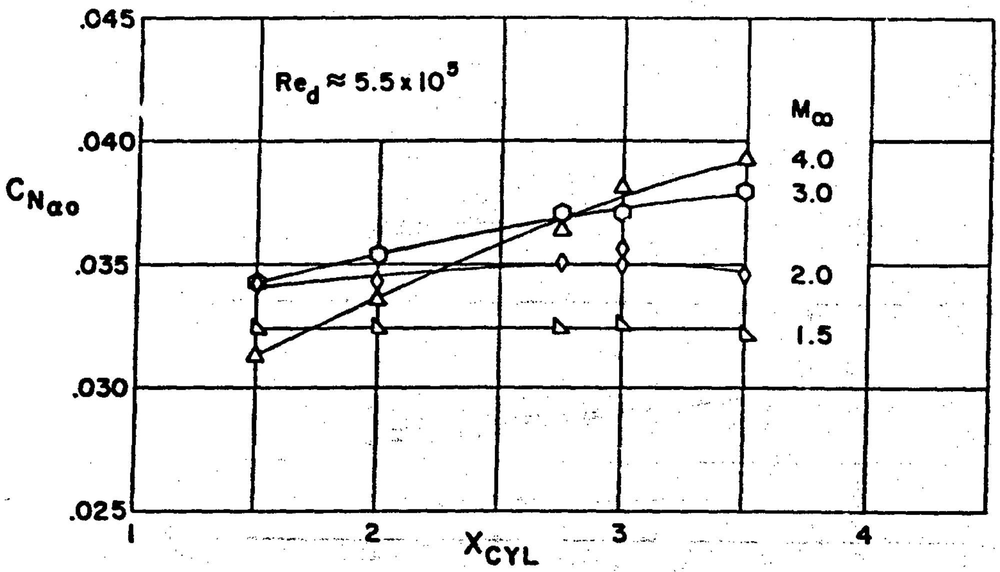


Figure 15. (C)Slope of Normal Force Coefficient Versus Afterbody Length(U)

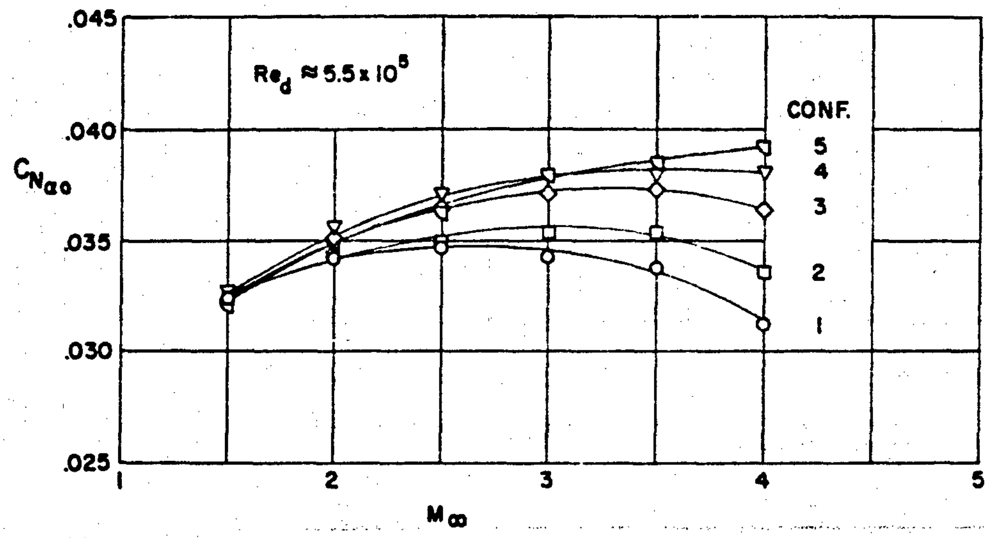


Figure 16. (C) Slope of Normal Force Coefficient Versus Mach Number (U)

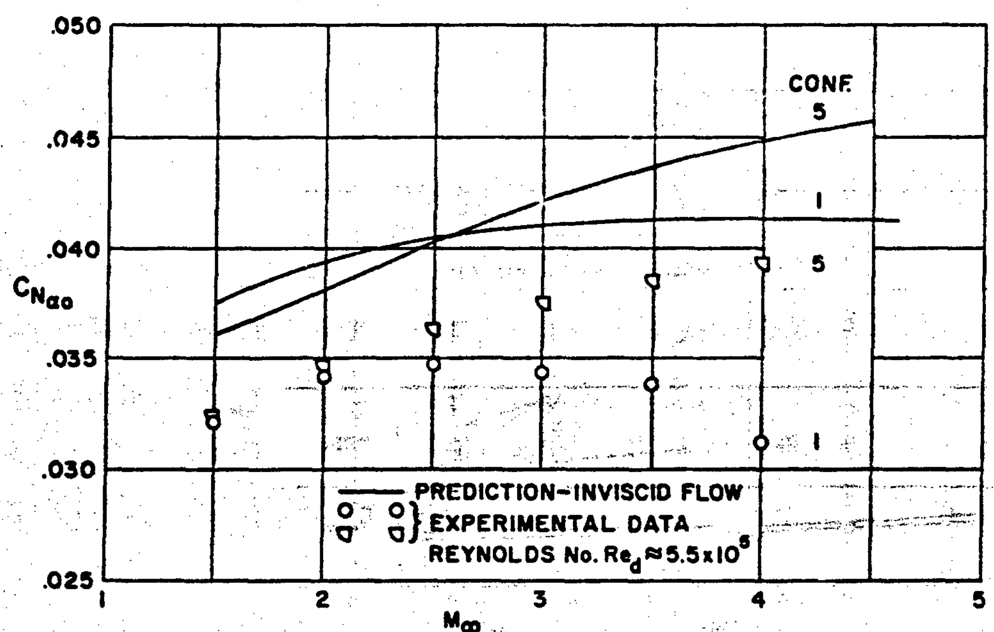


Figure 17. (C) Slope of Normal Force Coefficient Versus Mach Number - Comparison With Theory (U)

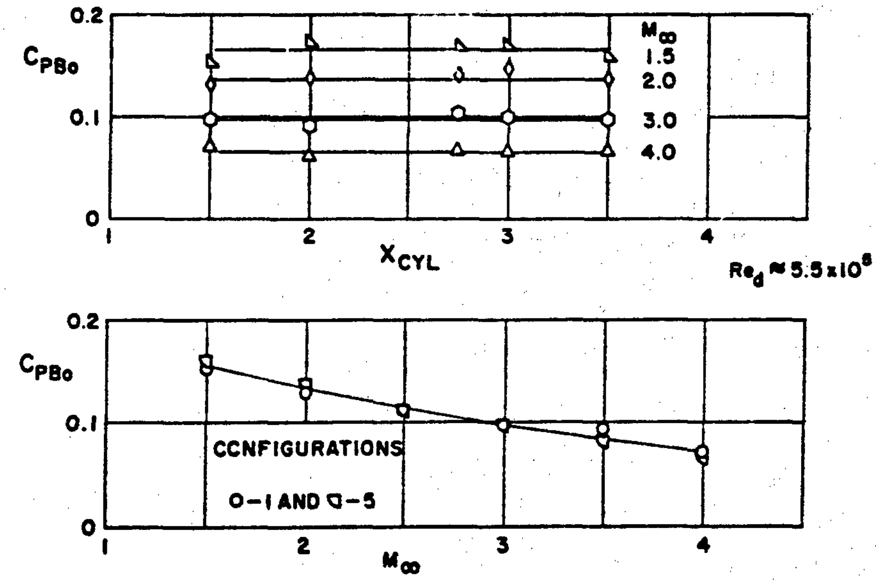


Figure 18. (C) Base Pressure Coefficient Versus Afterbody Length and Mach Number (U)

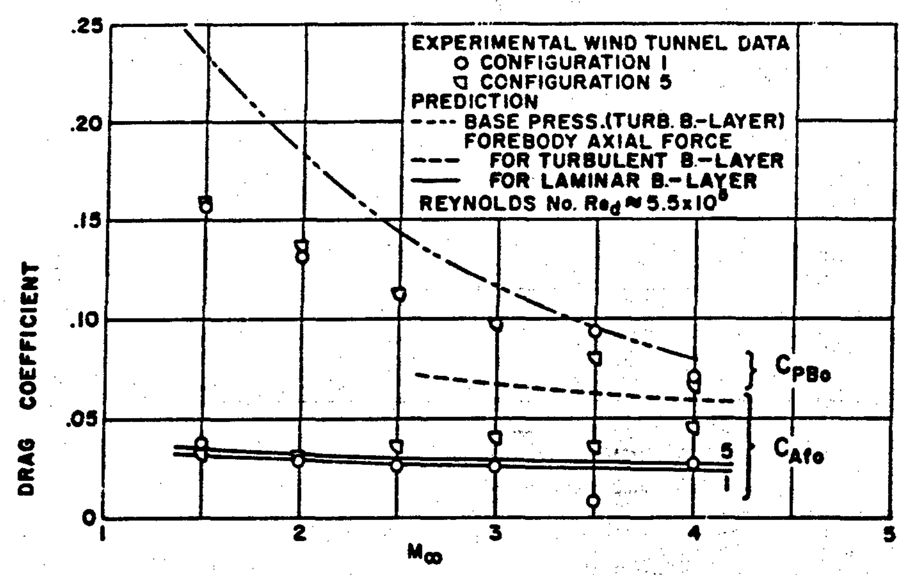


Figure 19.(C)Base Pressure Coefficient and Zero Lift Forebody Axial Force Coefficient Versus Mach Number-Comparison With Theory(U)

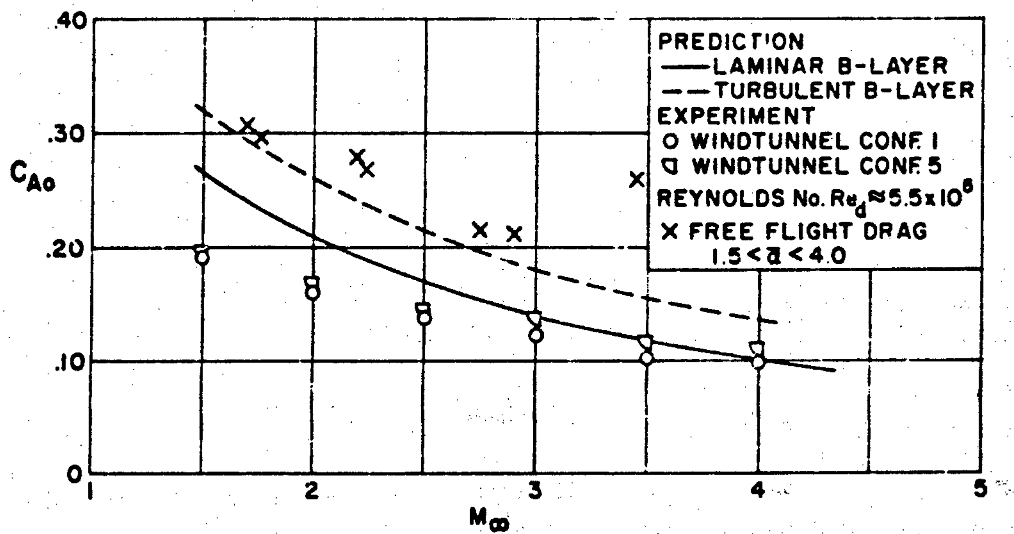


Figure 20. (C) Zero Lift Total Axial Force Coefficient Versus Mach Number - Comparison With Theory and Free Flight Test Data (U)

(UNCLASSIFIED) REFERENCES

1. W. O'Keefe and S. Wasserman. "Supersonic Wind Tunnel and Instrumented Free Flight Tests of Cone Cylinder, Mass Stabilized Flechettes (U)." Picatinny Arsenal (May 1967). To be published. CONFIDENTIAL

2. R. L. McCoy. "Estimation of Supersonic Static Aerodynamic Characteristics of Pointed Bodies of Revolution at Small Angles of Attack." BRL Communication. Unpublished.

3. V. Oskay. "Review of Cone Cylinder Flechette Tests." BRL Memorandum. Unpublished.

4. L. E. Schmidt, "The Dynamic Properties of Pure Cones and Cone Cylinders." BRL Memorandum Report No. 759. July 1954.

5. W. E. Buford and S. Chatunoff. "The Effects of Fineness Ratio and Mach Number on the Normal Force and Center of Pressure of Conical and Ogival Head Bodies." BRL Memorandum Report No. 760. February 1954.

6. J. C. McMullen. "Wind Tunnel Testing Facilities at the Ballistic Research Laboratories." BRL Memorandum Report No. 1292, July 1960.

7. R. F. Clippinger, J. H. Giese and W. C. Charter. "Tables of Supersonic Flows About Cone Cylinders." BRL Report No. 729, July 1950.

8. M. D. Van Dyke. "First and Second Order Theory of Supersonic Flow Past Bodies of Revolution," JAS, March 1951.

9. E. R. Van Driest, "Turbulent Boundary Layer in Compressible Fluids." JAS, March 1951.

10. D. R. Chapman. "An Analysis of Base Pressure at Supersonic Velocities and Comparison With Experiment," NACA Report No. 1051, 1951.

11. J. Sternberg, "Effect of a Boattail on the Base Pressure." May 1948, published by B. G. Karpov in BRL Report No. 1295, 1965.

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13. ABSTRACT

Wind tunnel force tests were performed to determine the influence of varying afterbody length on the aerodynamic characteristics of five slender cone cylinder flechette models. The test was performed in the supersonic wind tunnel No. 1 of the U. S. Army Ballistic Research Laboratory. Force and static stability parameters were determined at Mach numbers 1.5 to 4.0 at nearly constant Reynolds numbers. The results are presented and compared with theoretical data obtained from supersonic small disturbance theory. (U)

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